Integrated Feeding Network for Excitation of Dual-Linear Polarization in Series-Fed Antenna Lattice

Krzysztof Wincza, Izabela Slomian, Artur Rydosz, and Slawomir Gruszczynski
AGH University of Science and Technology
Al. Mickiewicza 30, 30-059 Krakow, Poland

***Abstract*— A concept of integrated feeding network designated for excitation of dual-linear polarization in series-fed microstrip antenna lattice has been proposed. The presented feeding network is composed of two Wilkinson power dividers and two 3-dB/90° directional couplers acting as a transmission-line crossover. As it has been shown such a compact network can be easily integrated with the recently developed antenna lattice, and therefore, allows for reduction of dissipation losses in the feeding network. The proposed concept has been experimentally verified by the design of an antenna lattice operating in 5.4 GHz frequency range.**

Keywords*— Antenna arrays; series feeding technique; antenna lattice; low-loss feeding networks.

I. INTRODUCTION

Microstrip technology is commonly used in many applications at microwave frequency range including the design of antenna arrays due to its advantages such as low-profile, low-weight and low-cost. The design techniques for microstrip antenna arrays have been constantlyy developed over the years which allowed for development of antenna arrays with improved properties, such as gain, bandwidth or polarization properties. One of the important issues in antenna arrays' design is the reduction of the dissipation losses in their feeding networks. It is known that a significant reduction of the feeding network's losses can be achieved with the use of a series feeding technique [1]-[3]. Among the recently developed solutions of series-fed antenna arrays attractive properties can be achieved with the use of an antenna lattice concept [4]-[5]. As it has been shown such antennas can feature dual-polarization properties and low dissipation losses since all radiating elements are fed in series along both horizontal and vertical lines with shortest possible transmission-line sections. It has to be noted that although such a feeding network minimizes the losses, asymmetric feeding of such antennas could result in the beam squint. A different solution to the antenna lattice design has been presented in [6], where a 4 x 4 antenna lattice has been fed with the use of four straight transmission lines coupled to the center lines of its every column and row. These four lines have been excited with the use of a modified Butler matrix for dual-circular polarization generation. The proposed solution has been further developed in [7], where a compact feeding network composed of four 3-dB/90° coupled-line directional couplers has been applied instead of the external Butler matrix. As it has been shown such a solution allows for achieving the same properties, i.e. dual-circular polarization properties of the antenna lattice with the use of an integrated structure.

This work was financially supported by the National Science Centre under SONATA Program (decision no. DEC-2011/03/D/ST7/01783).

In this paper, we propose a feeding network, which can be integrated with the previously developed antenna lattice [6] and which allows for generation dual-linear polarization. The proposed feeding network is composed of two reactive power dividers and two 3-dB/90° directional couplers that are used as a transmission-line crossover. As it is shown such a feeding network can be easily integrated at the center of the antenna lattice and allows for reduction of required electrical lengths of overall transmission lines in comparison to the known solutions employing only two reactive power dividers [8]. The presented concept has been experimentally verified by measurements of the manufactured integrated antenna lattice operating in 5.4 GHz frequency range.

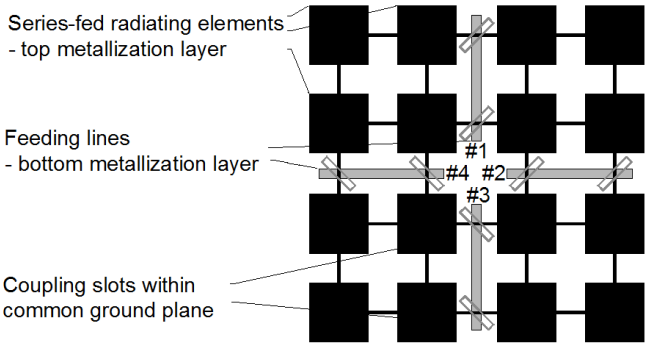


Fig. 1. Concept of a series-fed antenna lattice allowing for achieving dual-linear polarization properties.

II. CONCEPT OF DUAL-LINEAR ANTENNA LATTICE

A concept of the series-fed antenna lattice that features dual polarization properties is shown in Fig. 1. As it has been shown in [6] such an antenna lattice can generate dual-linear or dual-circular polarization when appropriate signals are delivered to all four input ports. To achieve dual-linear polarization the appropriate pairs of input ports, i.e. #1 & #3 and #2 & #4 have to be fed with equal-amplitude and in-phase signals. Such excitation signals can be ensured with the use of two separate power dividers feeding one of the pairs of input ports from the outer side and the other from the inner side of the antenna array [8], however, such an approach involves long transmission lines that have to be applied, and therefore increases the dissipation losses in the feeding network. The proposed approach designated for integration at the center part of the antenna lattice is shown in Fig. 2. As it is seen the proposed network is composed of two reactive power dividers, each exciting different linear polarization, and two 3-dB/90° coupled-line directional couplers used for realization of an unavoidable transmission-line crossover required for

appropriate feeding of the antenna lattice. It has to be underlined that the application of coupled-line couplers for crossover realization ensures a compact size of the entire feeding network which allows for integration at the center part of the antenna lattice. However, since the transmission line crossover realized as a tandem connection of two 3-dB/90° coupled-line couplers features 90° phase shift, it is necessary to add quarter-wave transmission lines at the appropriate outputs of reactive power dividers, as it is shown in Fig. 2

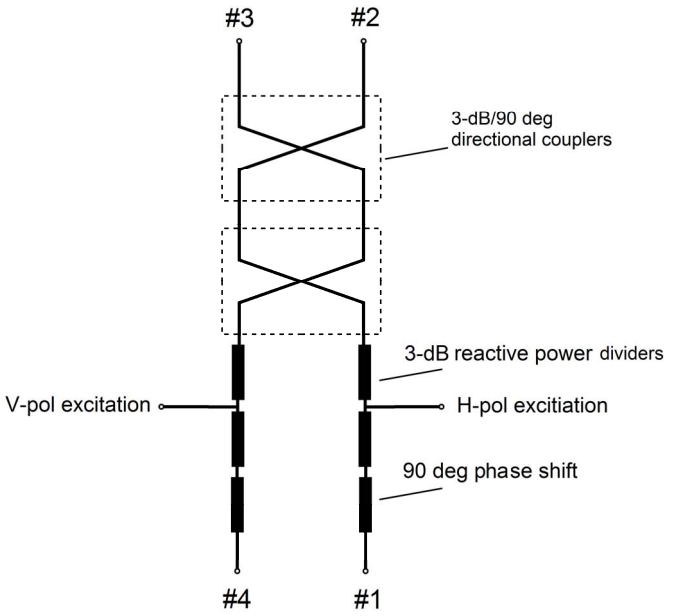


Fig. 2. Concept of a compact feeding network that allows for generation of dual-linear polarization in a series-fed antenna lattice.

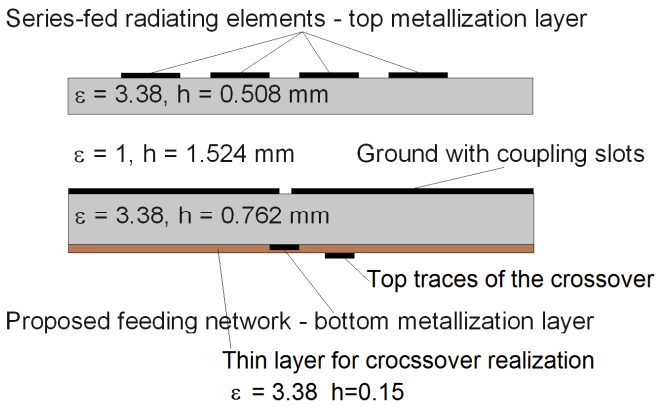


Fig. 3. Cross-sectional view of the dielectric structure used in the design of the integrated antenna lattice with dual-linear polarization properties.

III. Experimental Results

The proposed concept of a dual-linear series-fed antenna lattice fed by a compact integrated feeding network has been experimentally verified. The dielectric structure used for the design of the antenna lattice is shown in Fig. 3 and is the same as the one used for the dual-circular lattice presented recently in [7]. As 3-dB/90° directional couplers three-strip coupled-line couplers designed in an asymmetric structure and appropriately compensated have been used, which were previously utilized in the feeding network allowing for dual-circular polarization generation. Layout of the designed center part of the feeding network is shown in Fig. 4. As it is seen the developed feeding network features compact size and can be easily integrated in the antenna lattice. The designed dual-linear series-fed antenna lattice has been manufactured and measured. The measured S-parameters are shown in Fig. 5. As it is seen a good impedance match has been obtained at both input ports and the isolation between two ports generating orthogonal polarizations is better than 20 dB in the entire operational band. The obtained radiation patterns at both polarizations are shown in Fig. 6 and as it is seen the antenna lattice feature the same beamwidths at both polarizations. The measured gain is about 16 dBi and slightly differs for both polarization. This is most likely caused by the asymmetry of the structure in which coupled-line directional couplers have been realized. As it has been shown in [9] such couplers do not feature an ideal quadrature phases which could cause the differences observed in measurement results. Fig. 8 presents the photographs of the developed dual-linear series-fed antenna lattice showing the integrated feeding network.

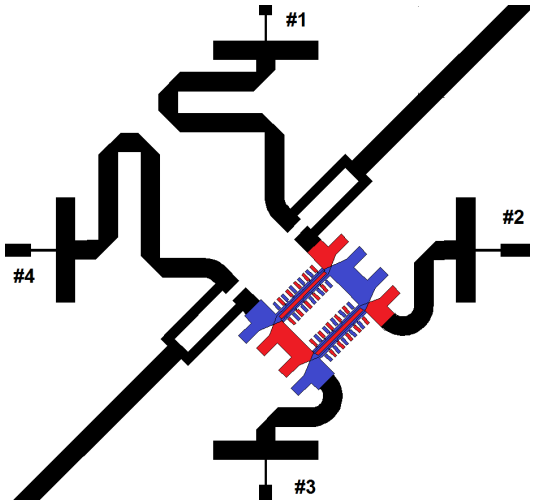


Fig. 4. Layout of the feeding netwok designated for integration at the center part of the antenna lattice.

IV. Conclusion

The concept of a compact feeding network designated for integration in a dual-linear series-fed antenna lattice has been proposed. The presented feeding network consists of two reactive power dividers which ensure appropriate signals feeding the respective input ports of the antenna lattice and two 3-dB/90° directional couplers which have been used to realize the required transmission-line crossover. It has been shown that such a network can be integrated at the center of the antenna lattice and thus allows for significant reduction of the overall length of the transmission lines used in the feeding network. Moreover, the proposed feeding network provides appropriate phase distribution across all inputs of the lattice comparing to the solution presented in e.g. [5], where

asymmetrical feeding of consecutive antenna elements are used. The proposed concept has been experimentally verified by measurements of the developed antenna lattice operating at 5.4 GHz frequency range. The obtained results confirm the correctness of the presented concept.

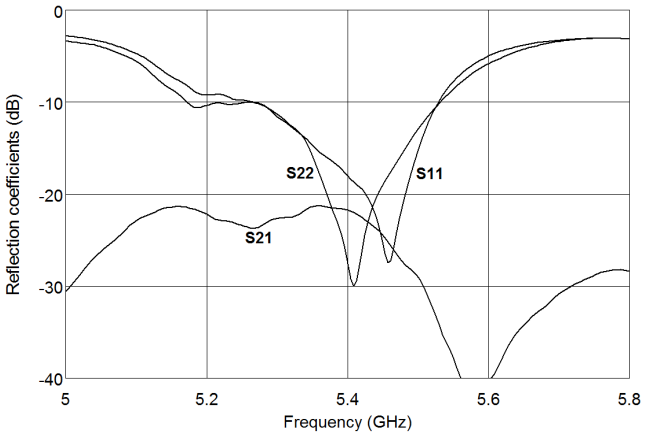


Fig. 5. Measured S-parameters of the developed integrated antenna lattice with dual-linear polarization properties.

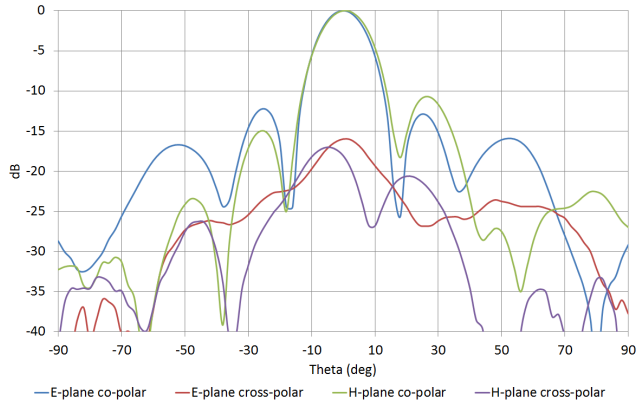


Fig. 6. Measured co-polar and cross-polar radiation patterns of the developed integrated antenna lattice with dual-linear polarization properties.

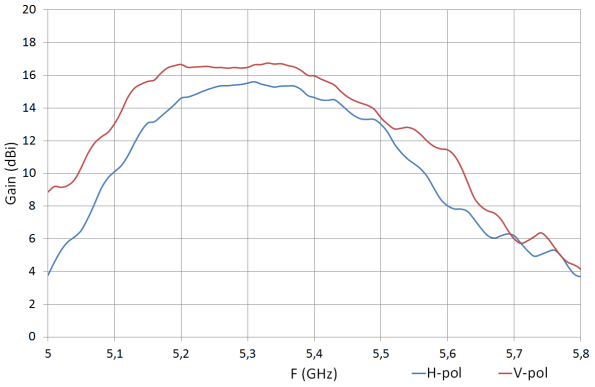
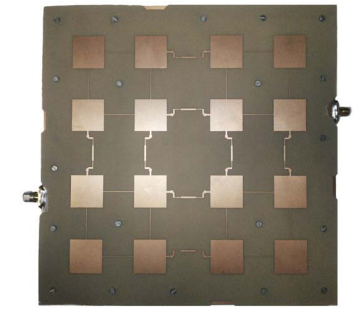
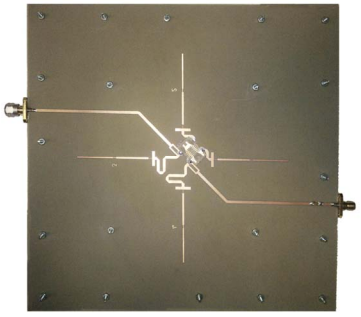


Fig. 7. Measured gain of the developed integrated antenna lattice with dual-linear polarization properties.



(a)



(b)

Fig. 8. Photographs of the manufactured antenna lattice. Top view shows series-fed radiating elements (a) and bottom view shows the developed integrated feeding network (b).

REFERENCES

[1] Y. Chong; D. Wenbin, "Microstrip series fed antenna array for millimeter wave automotive radar applications," *IEEE MTT-S International Microwave Workshop Series on Millimeter Wave Wireless Technology and Applications (IMWS)*, pp. 1-3, 18-20 Sept. 2012.

[2] T. Metzler, "Microstrip series arrays," *IEEE Trans. Antennas Propag.*, vol. AP-29, no. 1, Jan. 1981, pp. 174-178.

[3] K. Wincza, S. Gruszczynski, J. Borgosz, "Microstrip antenna array with series-fed 'through-element' coupled patches," *Electronics Letters*, vol.43, no.9, pp.487-489, 26 April 2007.

[4] S.-H. Hsu, Y.-J. Ren, K. Chang, "A dual-polarized planar-array antenna for S-band and X-band airborne applications," *IEEE Antennas and Propagation Magazine*, vol. 51, no. 4, pp. 70-78, Aug. 2009.

[5] S.-S. Zhong; X.-X. Yang; S.-C. Gao; J.-H. Cui, "Corner-fed microstrip antenna element and arrays for dual-polarization operation," *IEEE Transactions on Antennas and Propagation*, vol.50, no.10, pp.1473-1480, Oct 2002.

[6] I. Slomian, K. Wincza, S. Gruszczynski, "Series-fed microstrip antenna lattice with switched polarization utilizing Butler matrix," *IEEE Transactions on Antennas and Propagation*, vol. 62, no. 1, pp. 145-152, Jan. 2014.

[7] I. Slomian, K. Wincza, S. Gruszczynski, "Compact integrated feeding network for excitation of dual-circular polarization in series-fed antenna lattice", *IEEE Transactions on Antennas and Propagation*, vo. 62, no. 11, pp. 5876-5879, Nov. 2014.

[8] I. Slomian, K. Staszek, I. Piekarz, J. Sorocki, K. Wincza, S. Gruszczyński, „Dual polarized two port antenna lattice," *14th Mediterranean Microwave Symposium*, 12-14 Dec. 2014.

[9] K. Sachse, A. Sawicki, G. Jaworski, "Novel, multilayer coupled-line structures and their circuit applications," in Proc. 13th Int. Conf. on Microwaves, Radar & Wireless Communications, pt. 3 (invited paper), Wroclaw, Poland, May 2000, pp. 131-155.